MSL Landing Site Analysis for Planetary Protection

Ashwin R. Vasavada
MSL Deputy Project Scientist
Jet Propulsion Laboratory, California Institute of Technology

MSL 5th Landing Site Workshop

May 17, 2011

Background

- Early in the MSL Project, it was realized that a failure during EDL would pose a risk to the forward contamination of Mars. Specifically, the power source could become buried along with terrestrial microbes and Martian water or water ice, creating an environment favorable to propagation (i.e., an induced special region as described by the MEPAG SR-SAG, 2006).

- The Project made a major effort to assess this risk in detail [e.g., *Muirhead et al*., 2004; *Hecht and Vasavada*, 2006].

- The MSL PP Categorization states that 1-sigma landing error ellipses that address post-parachute-deploy failure modes must be limited to regions *not known to have extant water or water ice within 1 m of the surface.*

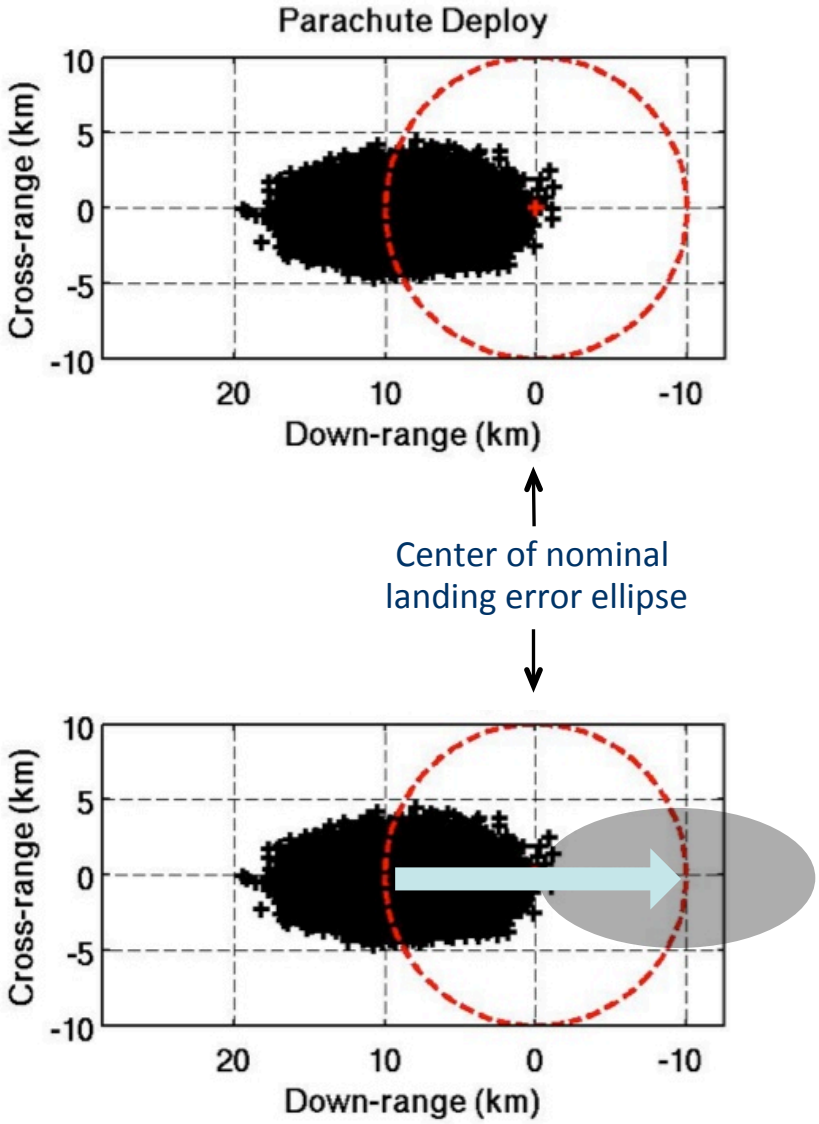
- The Project briefed the NASA Advisory Committee's PP subcommittee on May 10, 2011. A review with the Planetary Protection Office will be held before the site is selected by the NASA SMD AA.

Questions for this Talk

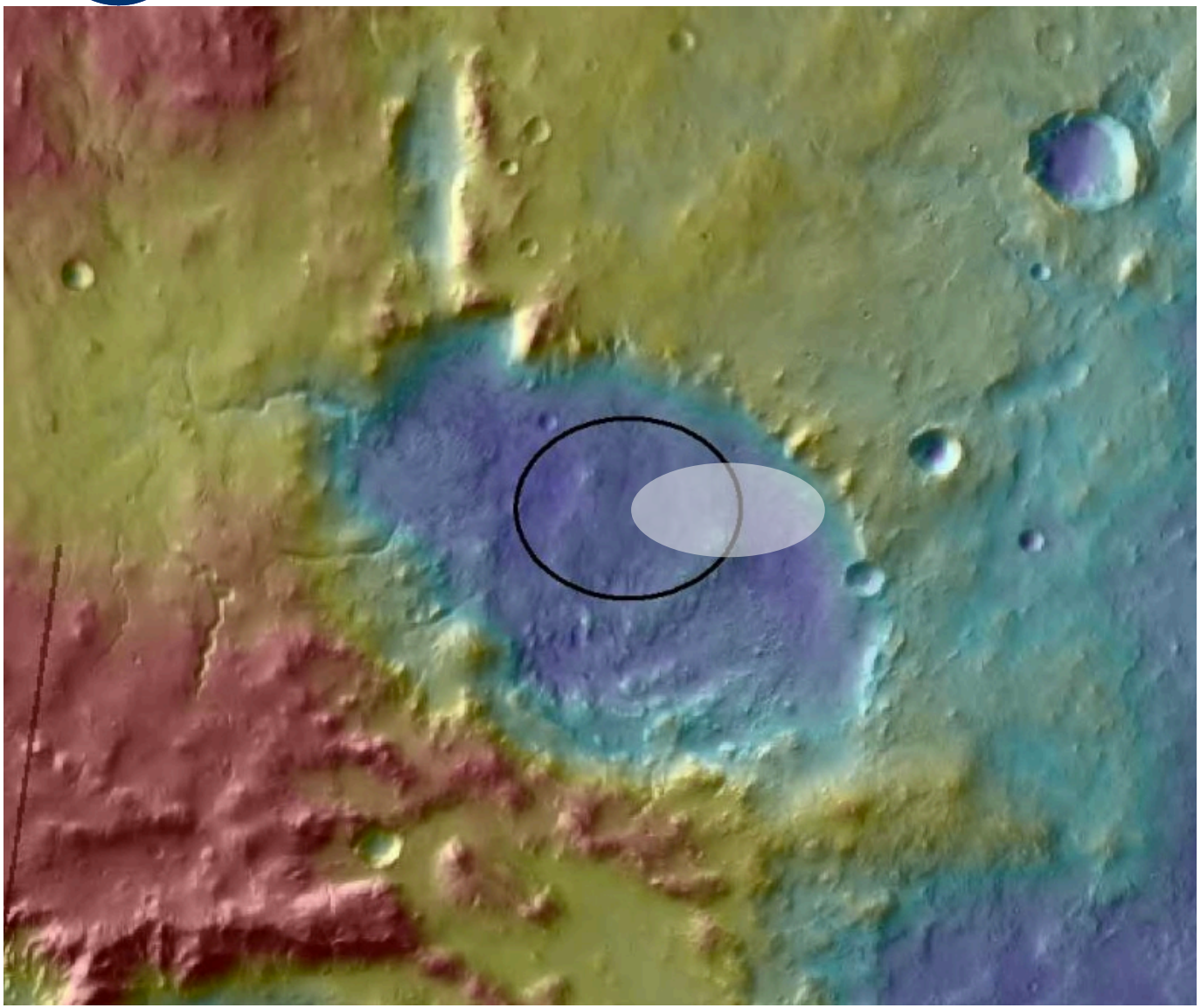
- What are the relevant regions of concern?
- Is there any water or water ice known to exist within 1 m of the surface in any of the regions of concern?
- Is there any reason to suspect undetected water ice? Use the following data to assess this possibility:
  - Thermophysical Properties and Temperatures
  - Slopes computed from landing site Digital Elevation Models
- Note: hydrated minerals are present in high abundance at some sites. Their potential to become induced special regions seems low, but is less understood at this point.

Post-Parachute Failure Ellipses

- For a conservative assumption about initial attitude knowledge, parachute deploy occurs ~10 km up range of the center of the ellipse.
- A failure in parachute deployment would result in impact of the vehicle somewhere within a similarly sized cloud of points centered ~9.7 km downrange of the target (computed by MSL EDL Team).

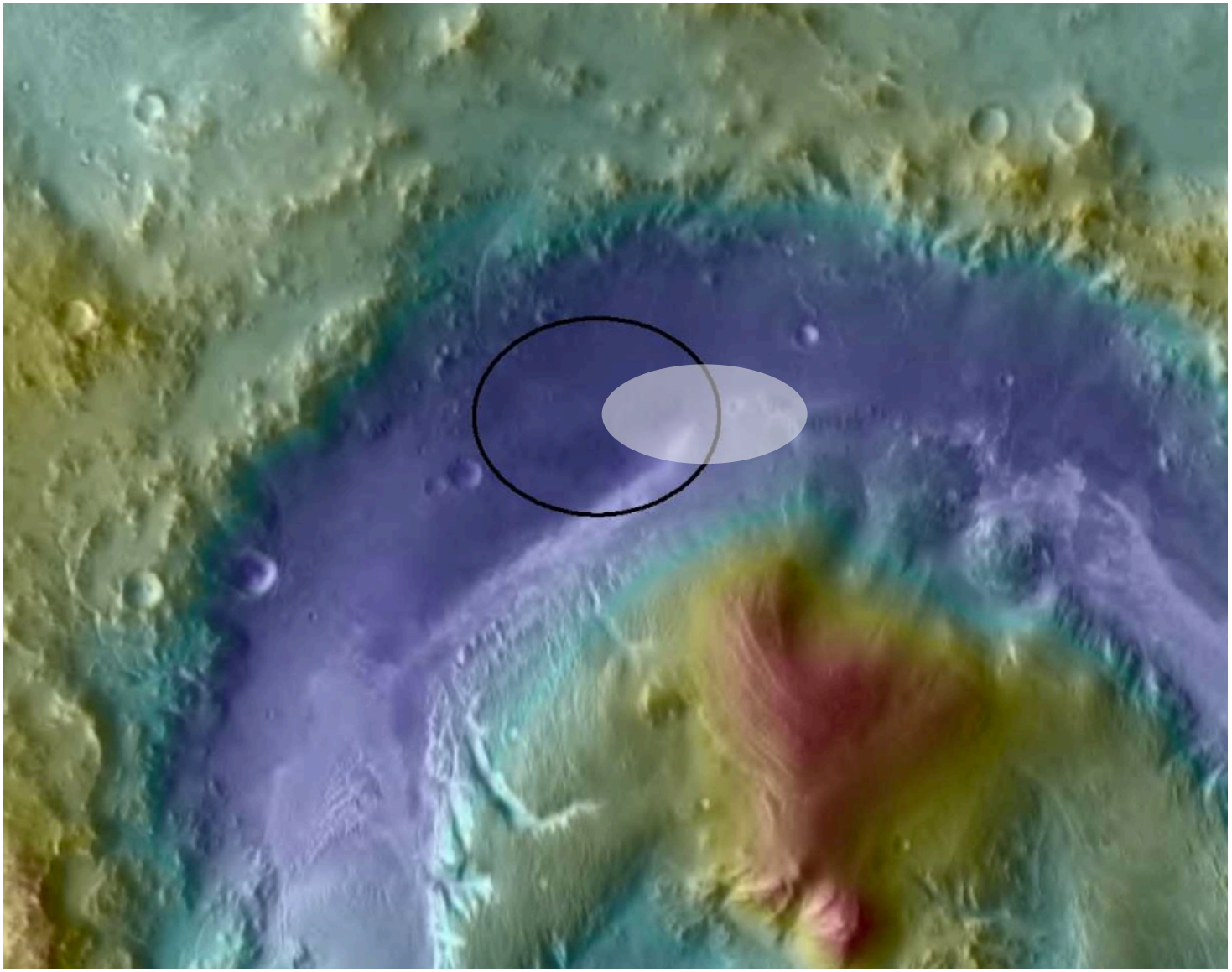


Eberswalde (24°S)



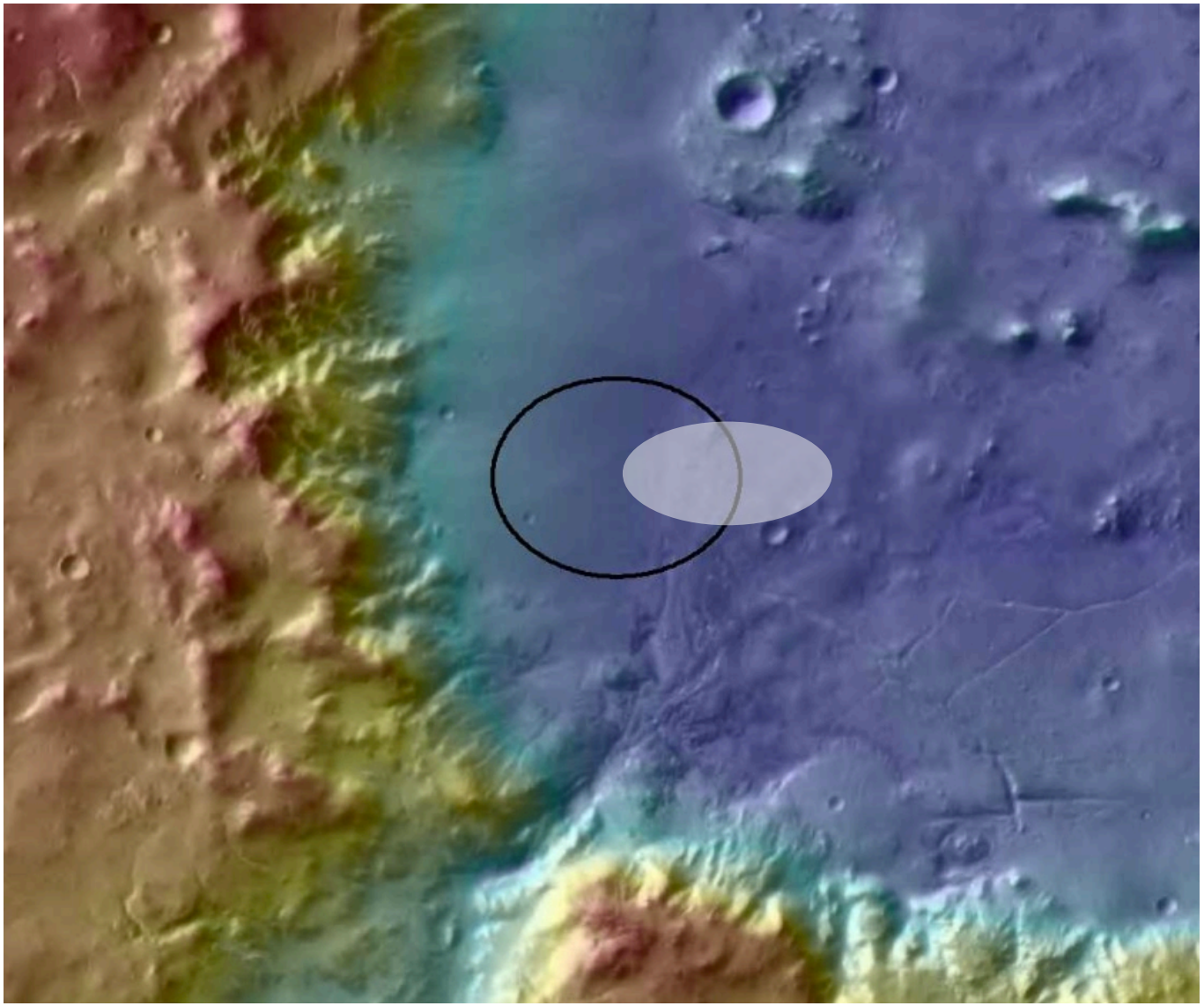
- Nominal 25×20-km landing error ellipse (solid line).
- Region of impact for post chute deploy failure modes (shaded ellipse).

Gale (5°S)



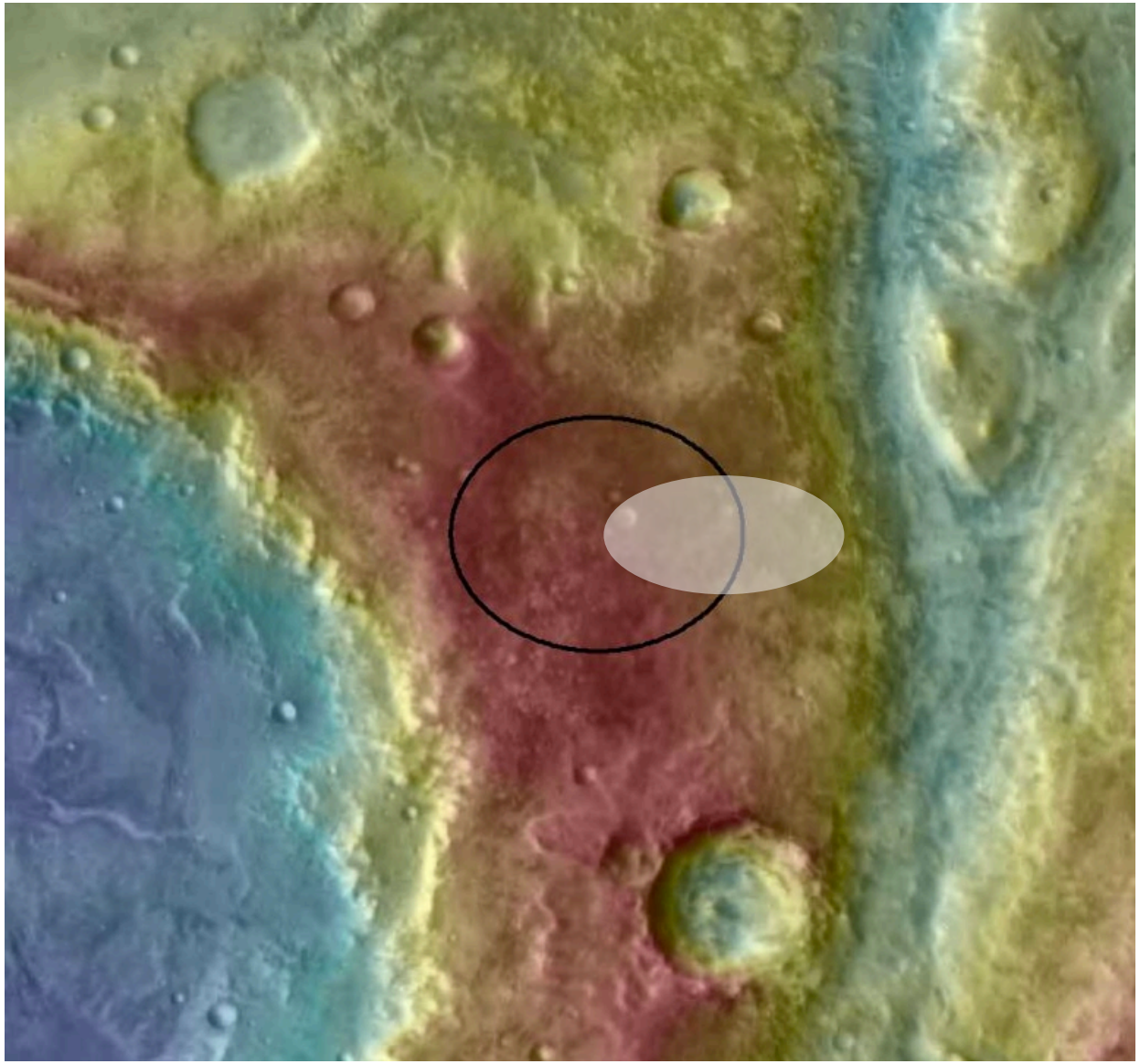
- Nominal 25×20-km landing error ellipse (solid line).
- Region of impact for post chute deploy failure modes (shaded ellipse).

Holden (26°S)



- Nominal 25×20-km landing error ellipse (solid line).
- Region of impact for post chute deploy failure modes (shaded ellipse).

Mawrth (24°N)



- Nominal 25×20-km landing error ellipse (solid line).
- Region of impact for post chute deploy failure modes (shaded ellipse).

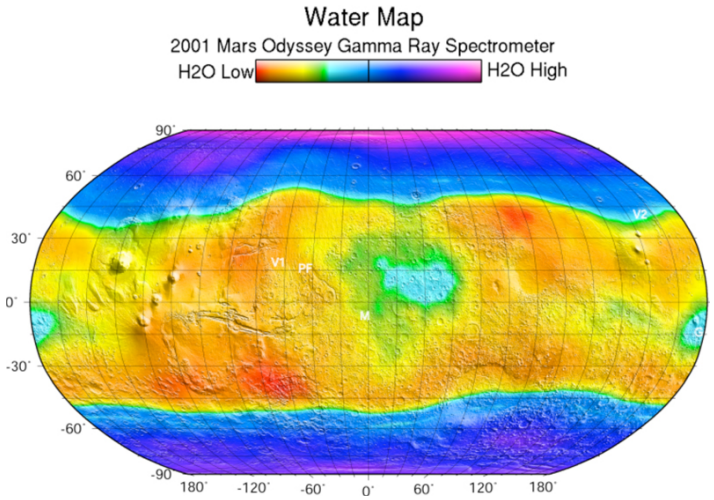
Water and Water Ice

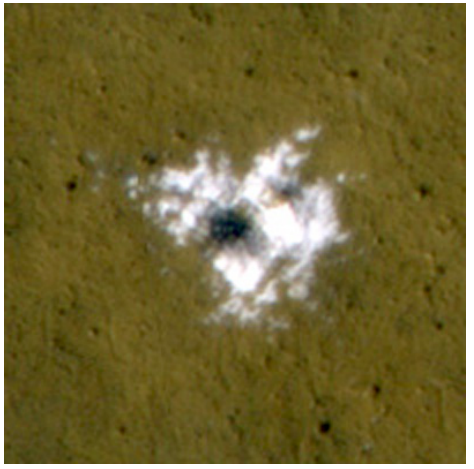
Water/ice near the MSL sites could take any of several forms:

- Seasonal frost: very small %, at surface; not relevant
- Adsorbed water: small %, at surface; not relevant
- Extant liquid water: no gully morphologies observed in the MSL landing site regions
- Exposed perennial ice or icy mantles: none observed at landing site latitudes
- Buried massive ice (i.e., glaciers): no radar signatures or glacial/ lobate morphologies in the MSL landing site regions
- Buried ground ice (i.e., in a permafrost zone): this is investigated further in the following pages

Known Ground Ice

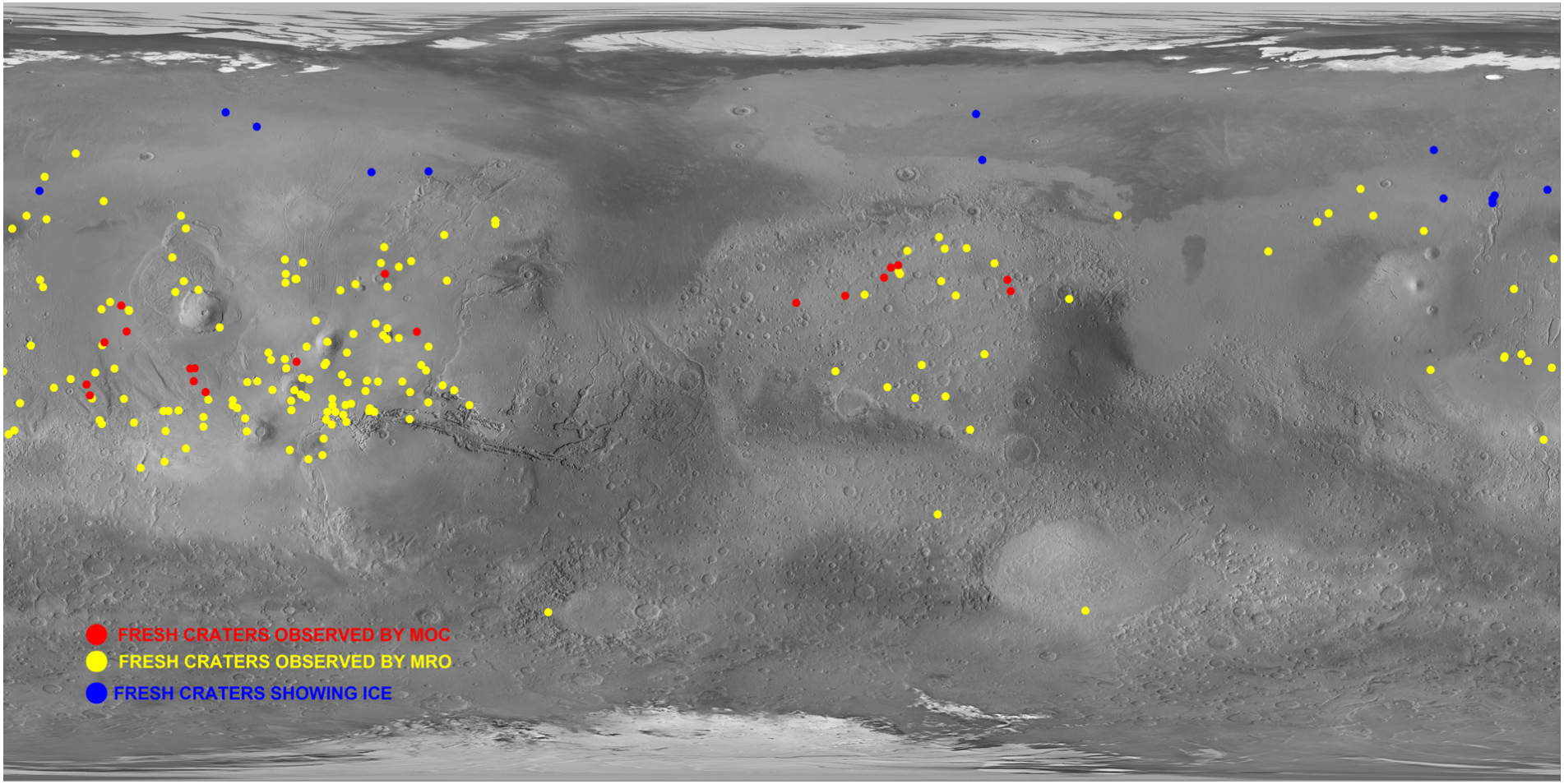
- Stable ground ice is in diffusive and thermal equilibrium with the present atmosphere and climate. Observations by the Mars Odyssey Gamma Ray Spectrometer suite closely match model predictions. Neither indicate ground ice at the MSL sites.
- Recent impacts reveal nearly pure ground ice at mid latitudes, down to 35°. Their more equatorward distribution may indicate deposition under a slightly higher-humidity climate (but shorter than orbital/ axial cycles).
- Models created to explain the distribution and depth of these relic deposits do not predict ground ice at the MSL landing sites.





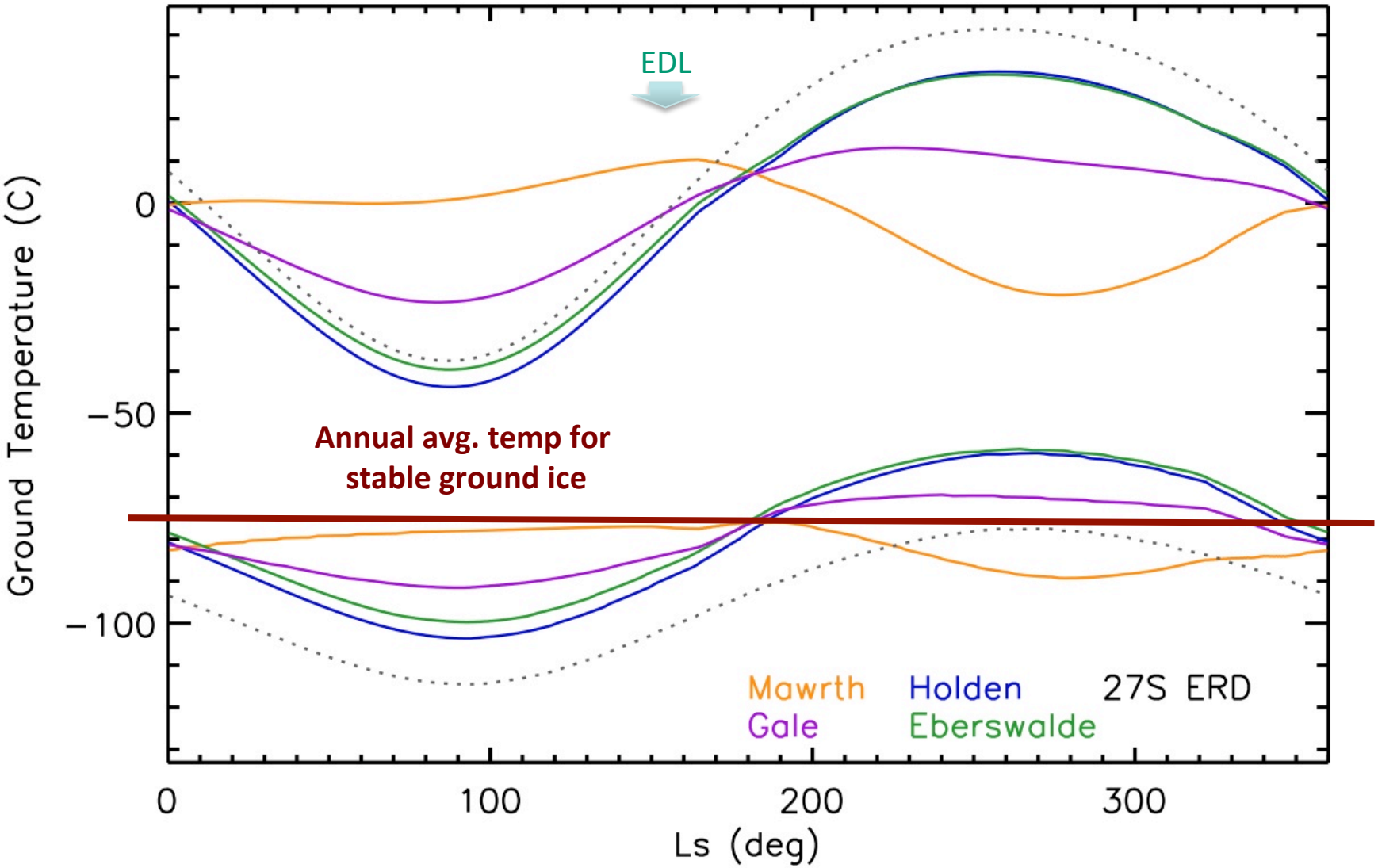
HiRISE Color Image
(meter-scale crater)

New Impact Craters



About 200 fresh impact sites have been found. MGS-MOC found craters in global maps at 250 m/pxl. MRO-CTX repeat coverage in high albedo areas is about 10% of planet.

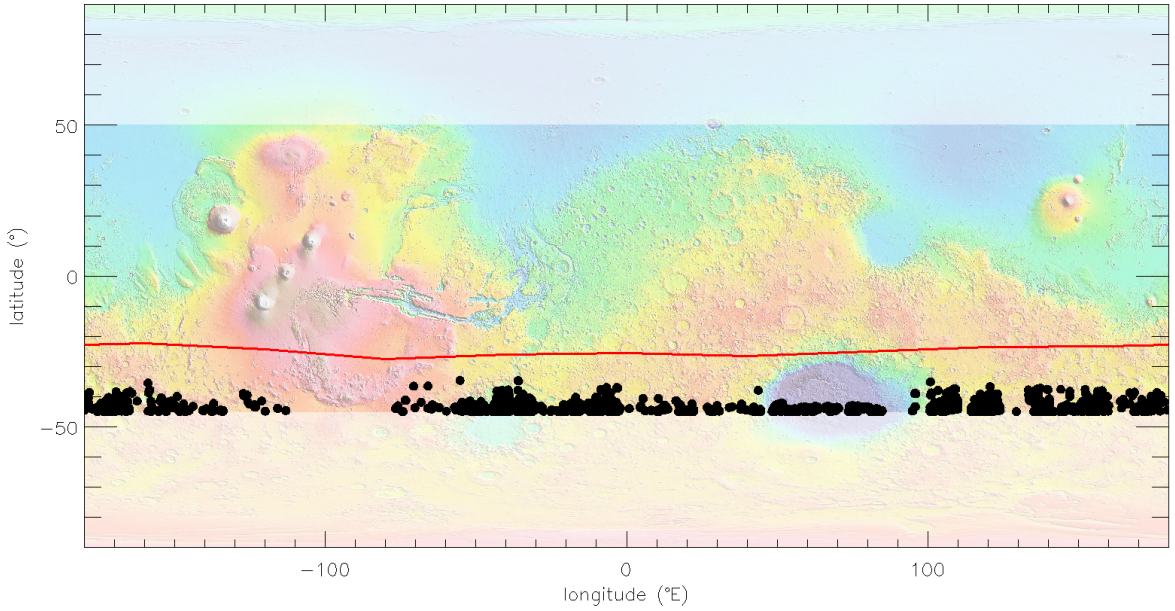
Diurnal and Annual Temperatures



Inferred Ground Ice

- A recent set of studies by *Vincendon et al*. [2010a, 2010b] has inferred ground ice at the latitudes of two MSL sites. They compared spectral detections of seasonal CO_2 frost with a modeled distribution. Frost is predicted, but absent, on steep, poleward-facing slopes down to 25°S.

- They explain the mismatch by the presence of high thermal inertia material on these slopes. They argue that ground ice would be locally stable within 0.5 m of such surfaces, and would have the proposed thermal behavior.



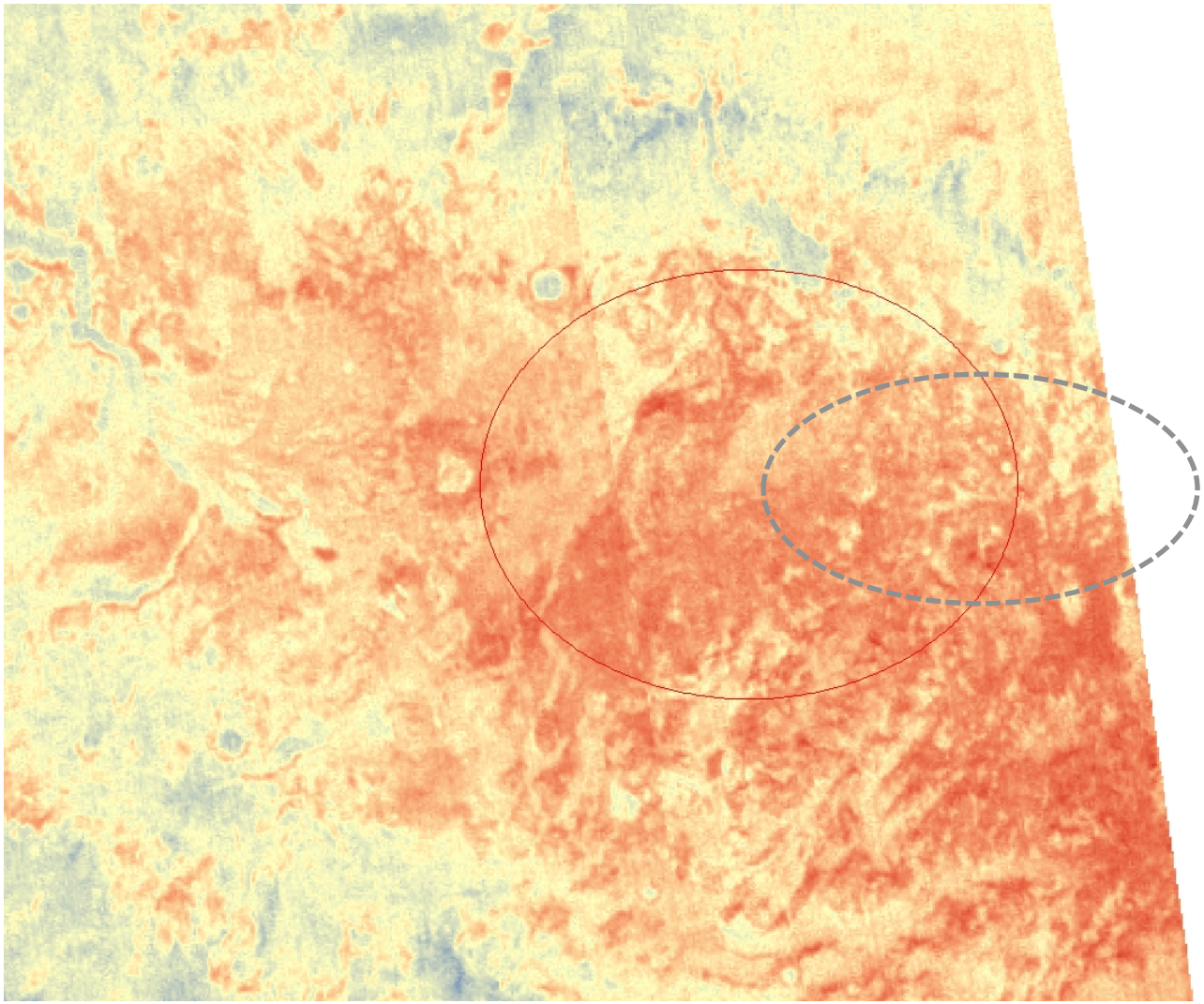
CO_2 ice Observed

CO_2 ice Expected

Application to MSL Sites

- To address the potential for ground ice including the *Vincendon et al*. hypothesis, we have compiled temperature and slope data for each of the MSL landing sites.
- Diurnal and annual surface temperatures are predicted by global numerical models and are validated against observations by MGS-TES and ODY-THEMIS.
- THEMIS-derived high-resolution temperature maps allow assessment of thermophysical properties and reveal local variability due to thermal inertia, slopes, shadows, etc.
- Slope maps at several baselines relevant to local topography are created from stereo imagery. Stereo imagery does not cover full region of concern in some cases. Mono images are used to identify any potentially relevant terrain.

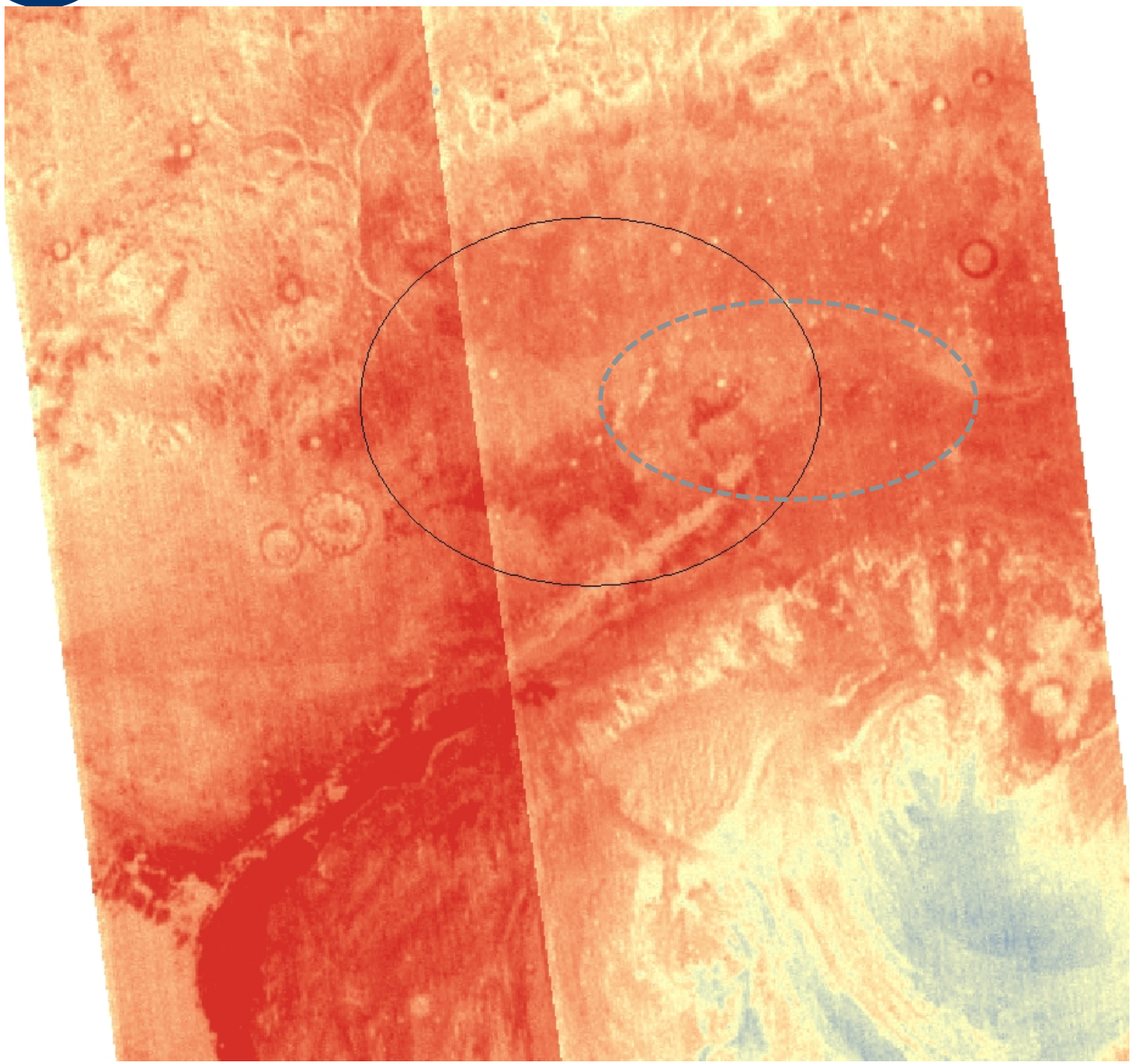
Winter/Night - Eberswalde



- Eberswalde Crater and go-to region at annual minimum temperature; night in winter (L_s=90).
- Color stretch is from 150 to 190K.

THEMIS-derived temperature map.
R. Fergason (USGS).

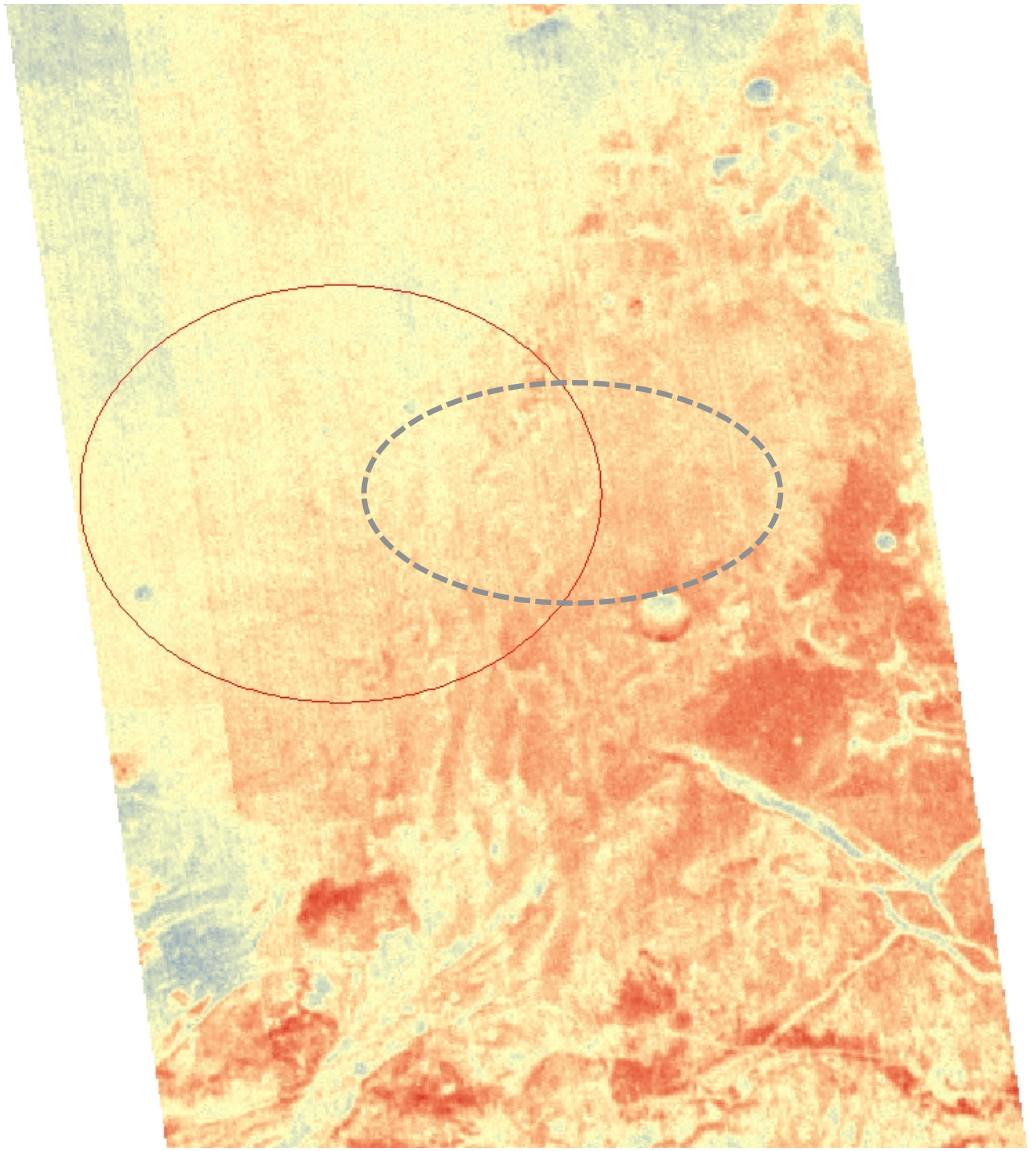
Winter/Night - Gale



- Eberswalde Crater and go-to region at annual minimum temperature; night in winter (L_s=90).
- Color stretch is from 150 to 190K.

THEMIS-derived temperature map.
R. Fergason (USGS).

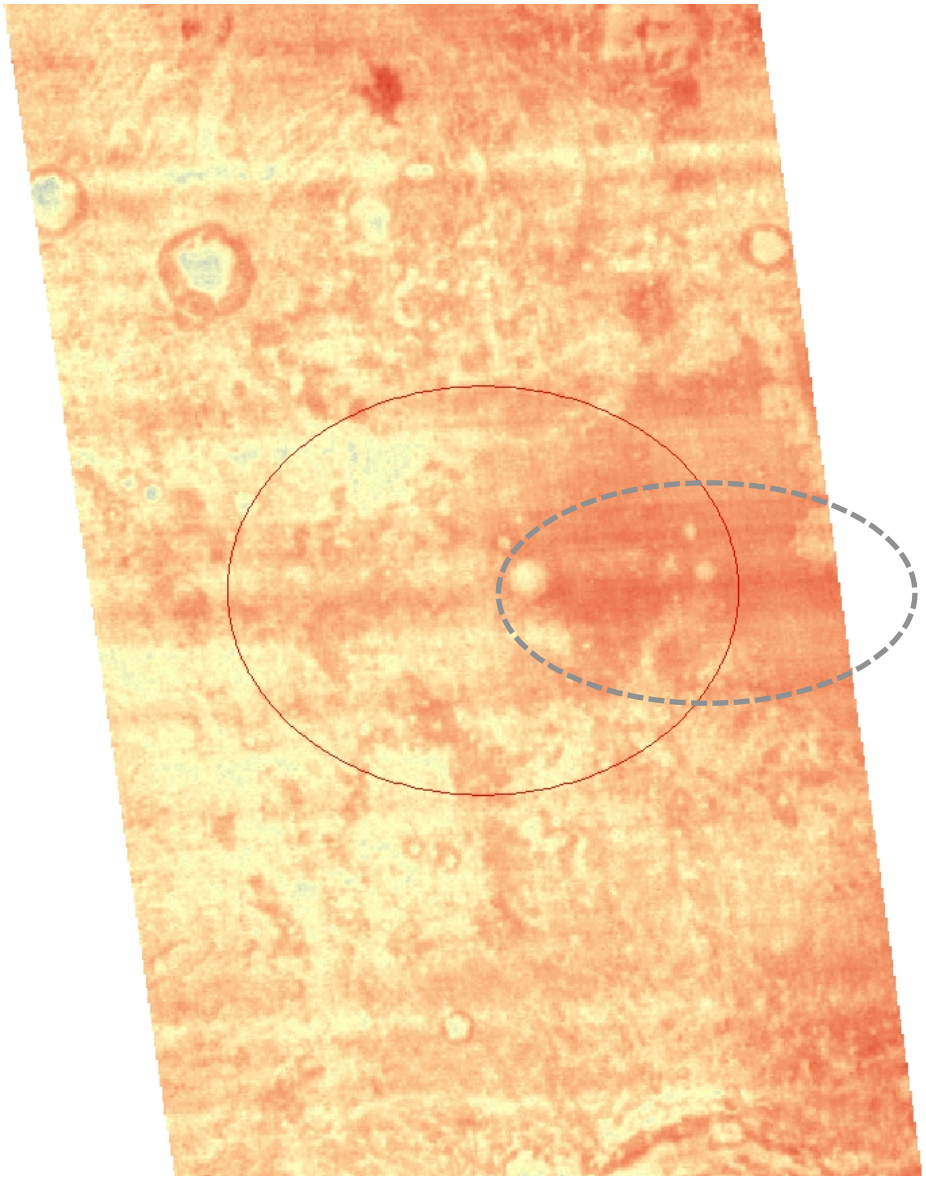
Winter/Night - Holden

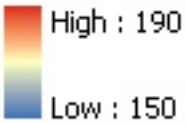


- Holden Crater and go-to region at annual minimum temperature; night in winter (L_s=90).
- Color stretch is from 150 to 190K.

THEMIS-derived temperature map.
R. Fergason (USGS).

Winter/Night - Mawrth

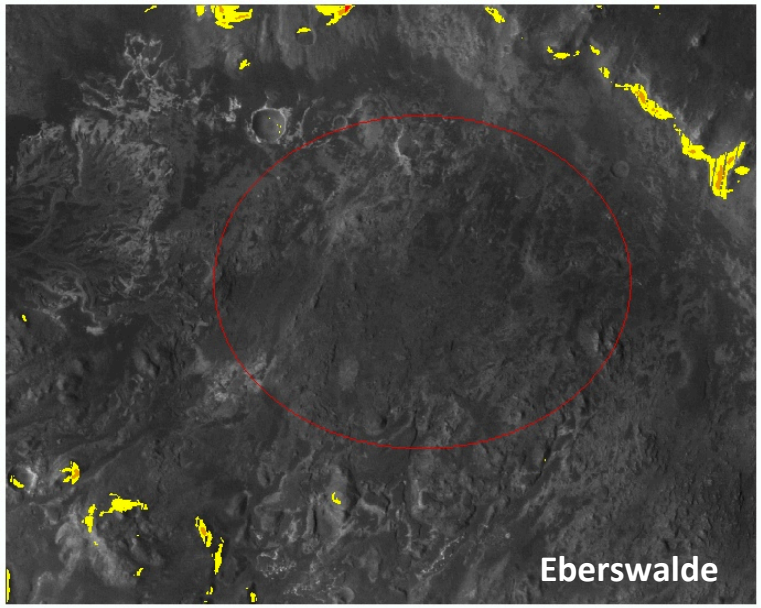


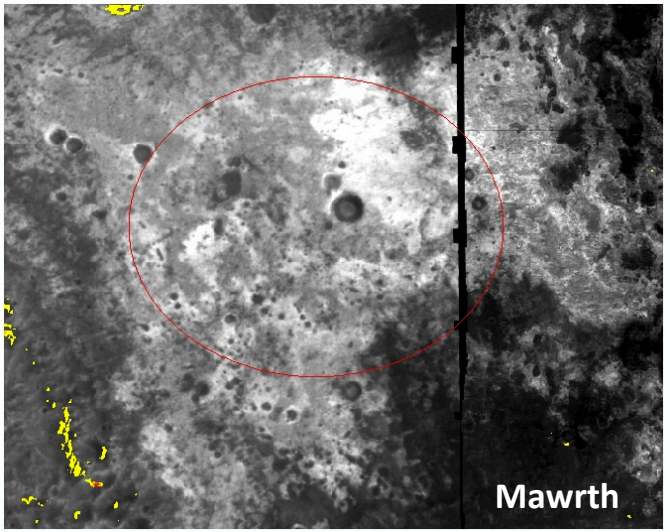


- Eberswalde Crater and go-to region at annual minimum temperature; night in winter (L_s=90).
- Color stretch is from 150 to 190K.

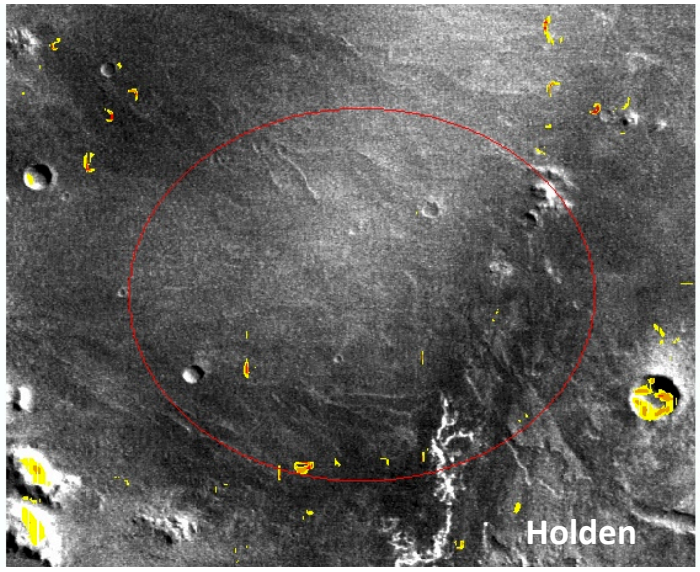
THEMIS-derived temperature map.
R. Fergason (USGS).

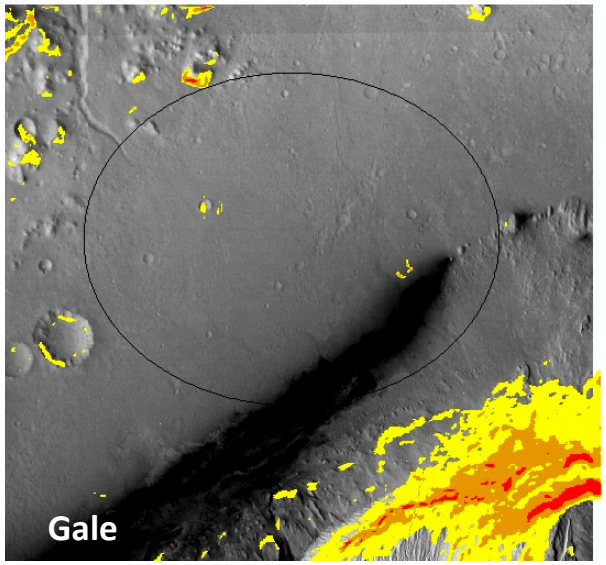
Slopes at 50-m Baseline





Slopes derived from MEX-HRSC. Digital elevation model of K. Gwinner (DLR-ESA) analyzed by F. Calef (JPL).



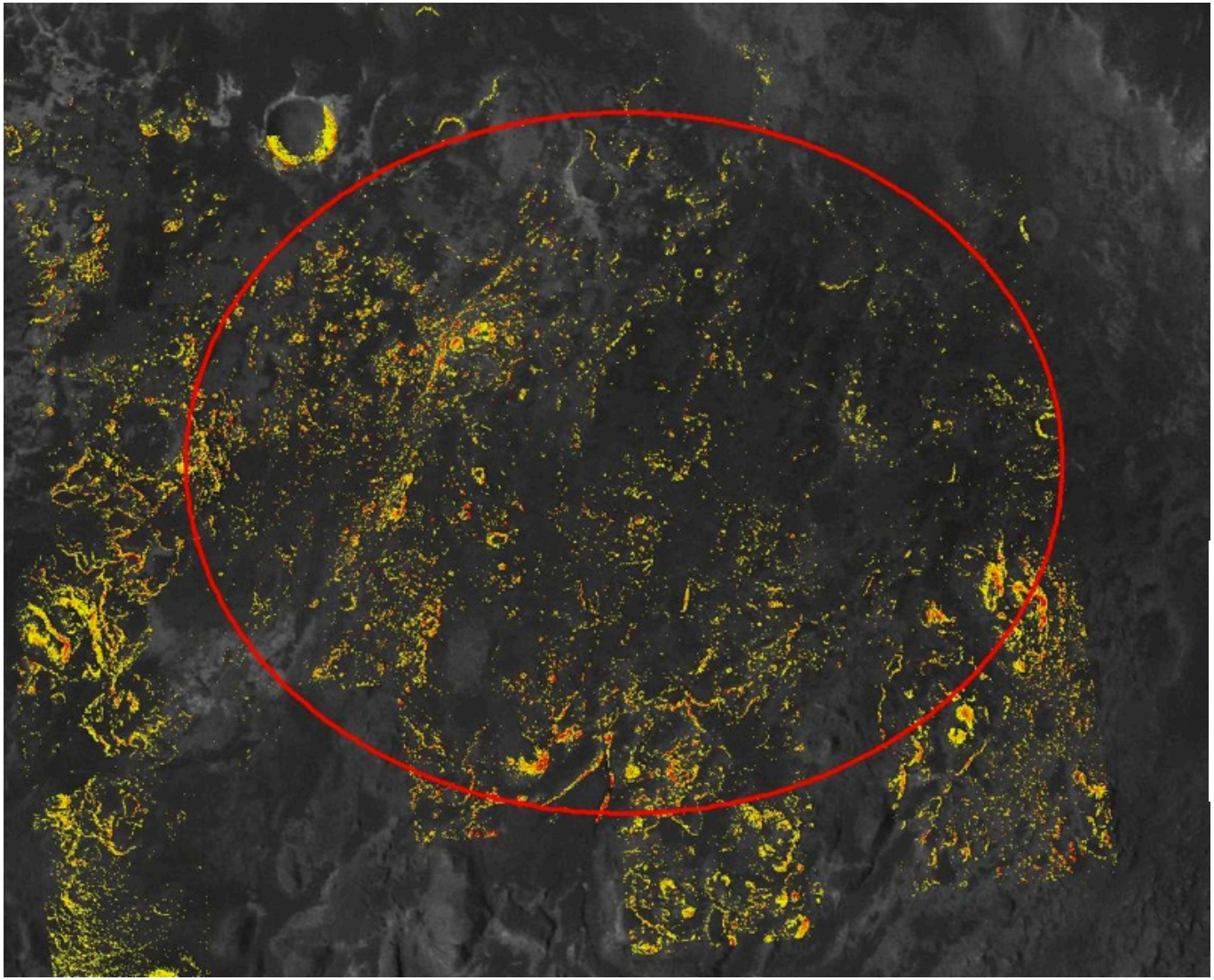


5-m Baseline Slope Distributions

Site/DTM	Fraction of Ellipse	RMS Slope	98th %ile Slope	99th %ile Slope	Slopes > 15°	Slopes > 20°	Slopes > 25°
Eberswalde Total	**84%**	**7.03**	**21.3**	**24.9**	**5.93%**	**2.45%**	**0.94%**
Eberswalde W	17%	8.29	23.1	26.9	7.49%	3.31%	1.38%
Eberswalde WC	26%	6.19	23.3	27.3	7.30%	3.28%	1.43%
Eberswalde EC	21%	6.17	17.5	20.9	3.23%	1.15%	0.38%
Eberswalde E	19%	7.75	20.1	22.9	5.69%	1.99%	0.50%
Mawrth 2 Total	**95%**	**6.00**	**15.5**	**18.1**	**2.15%**	**0.57%**	**0.15%**
Mawrth 2 W	16%	5.72	14.9	17.7	1.88%	0.51%	0.13%
Mawrth 2 WC	25%	5.81	14.7	17.1	1.74%	0.42%	0.10%
Mawrth 2 C	22%	6.27	16.1	18.9	2.53%	0.71%	0.20%
Mawrth 2 SC	8%	5.65	14.5	16.9	1.63%	0.40%	0.10%
Mawrth 2	23%	6.25	16.3	18.9	2.60%	0.72%	0.20%
Gale Total	**62%**	**4.46**	**10.9**	**12.9**	**0.48%**	**0.12%**	**0.04%**
Gale W	17%	4.00	9.9	11.9	0.37%	0.06%	0.00%
Gale C	21%	4.21	10.3	12.1	0.29%	0.04%	0.01%
Gale	23%	4.96	11.9	14.1	0.73%	0.22%	0.09%
Gale T1		*17.16*	*41.3*	*44.9*	*33.48%*	*22.15%*	*14.85%*
Holden Total	**50%**	**4.15**	**10.3**	**12.3**	**0.39%**	**0.08%**	**0.02%**
Holden	9%	4.38	10.1	11.9	0.26%	0.05%	0.01%
Holden C	17%	4.63	10.1	11.5	0.17%	0.01%	0.00%
Holden E	25%	3.70	10.5	13.1	0.58%	0.14%	0.03%
Holden T1		*6.45*	*17.7*	*21.1*	*3.41%*	*1.21%*	*0.49%*
Spirit		**3.73**	**10.1**	**12.1**	**0.36%**	**0.05%**	**0.01%**
Opportunity		**3.27**	**8.1**	**9.5**	**0.06%**	**0.00%**	**0.00%**
Phoenix		**1.85**	**4.1**	**4.5**	**0.00%**	**0.00%**	**0.00%**

[R. Kirk (USGS); presented at 4th MSL Landing Site Workshop]

Slopes at 1-m Baseline

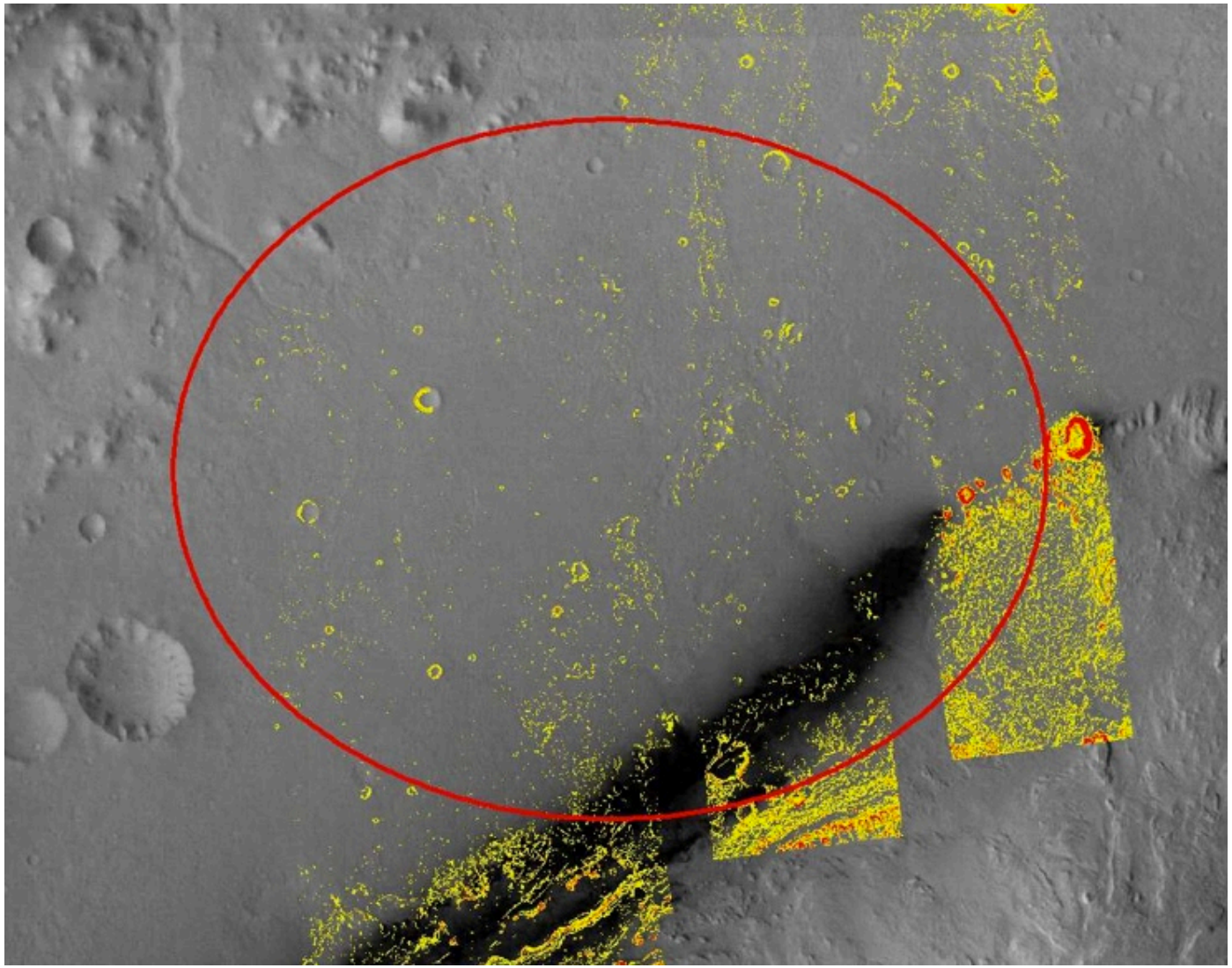


Eberswalde

Slopes derived from HiRISE digital elevation model of R. Kirk (USGS) by F. Calef (JPL).

- <15 degrees
- 15-20 degrees
- 20-25 degrees
- >25 degrees

Slopes at 1-m Baseline

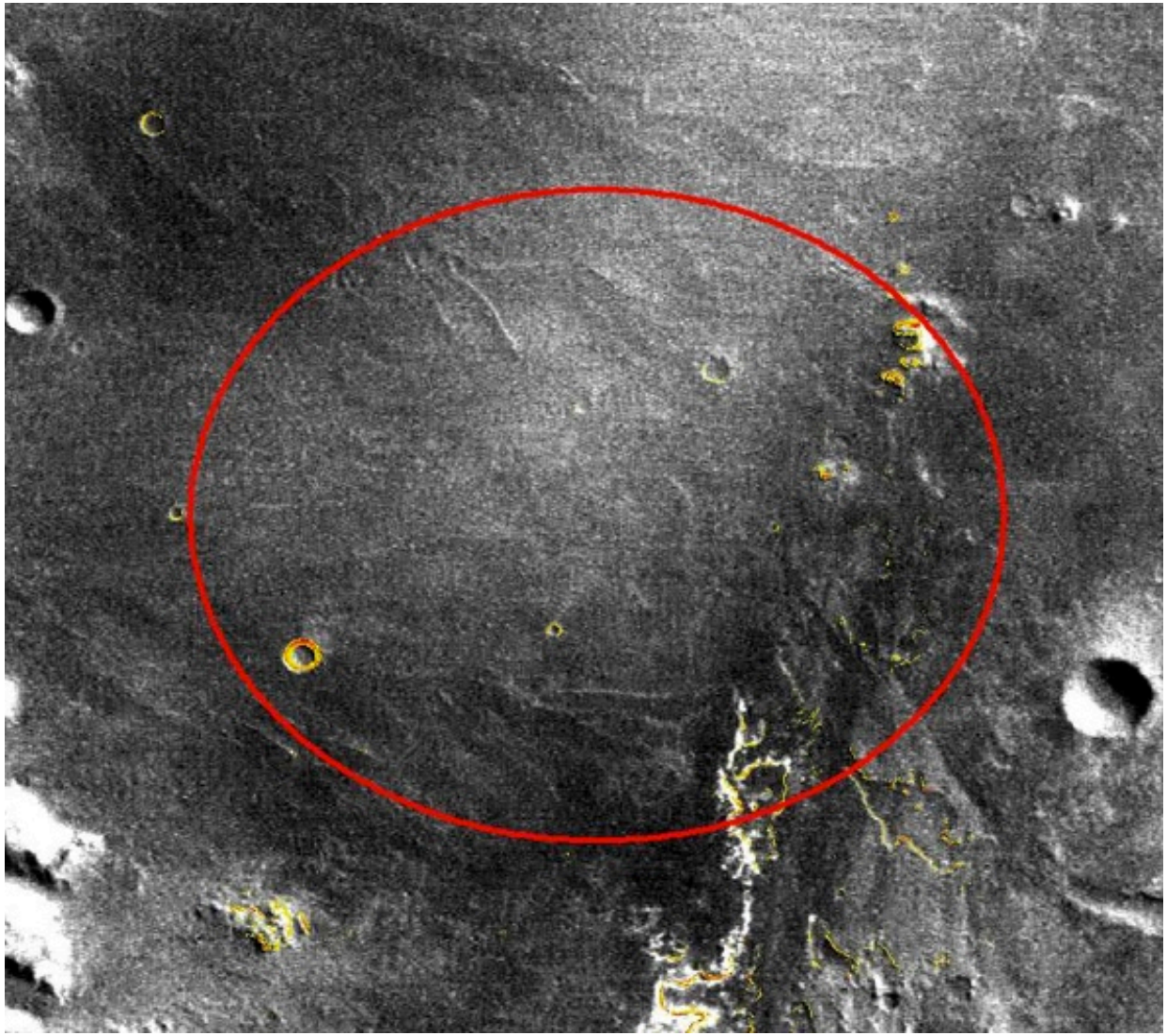


Gale

Slopes derived from HiRISE digital elevation model of R. Kirk (USGS) by F. Calef (JPL).

- <15 degrees
- 15-20 degrees
- 20-25 degrees
- >25 degrees

Slopes at 1-m Baseline

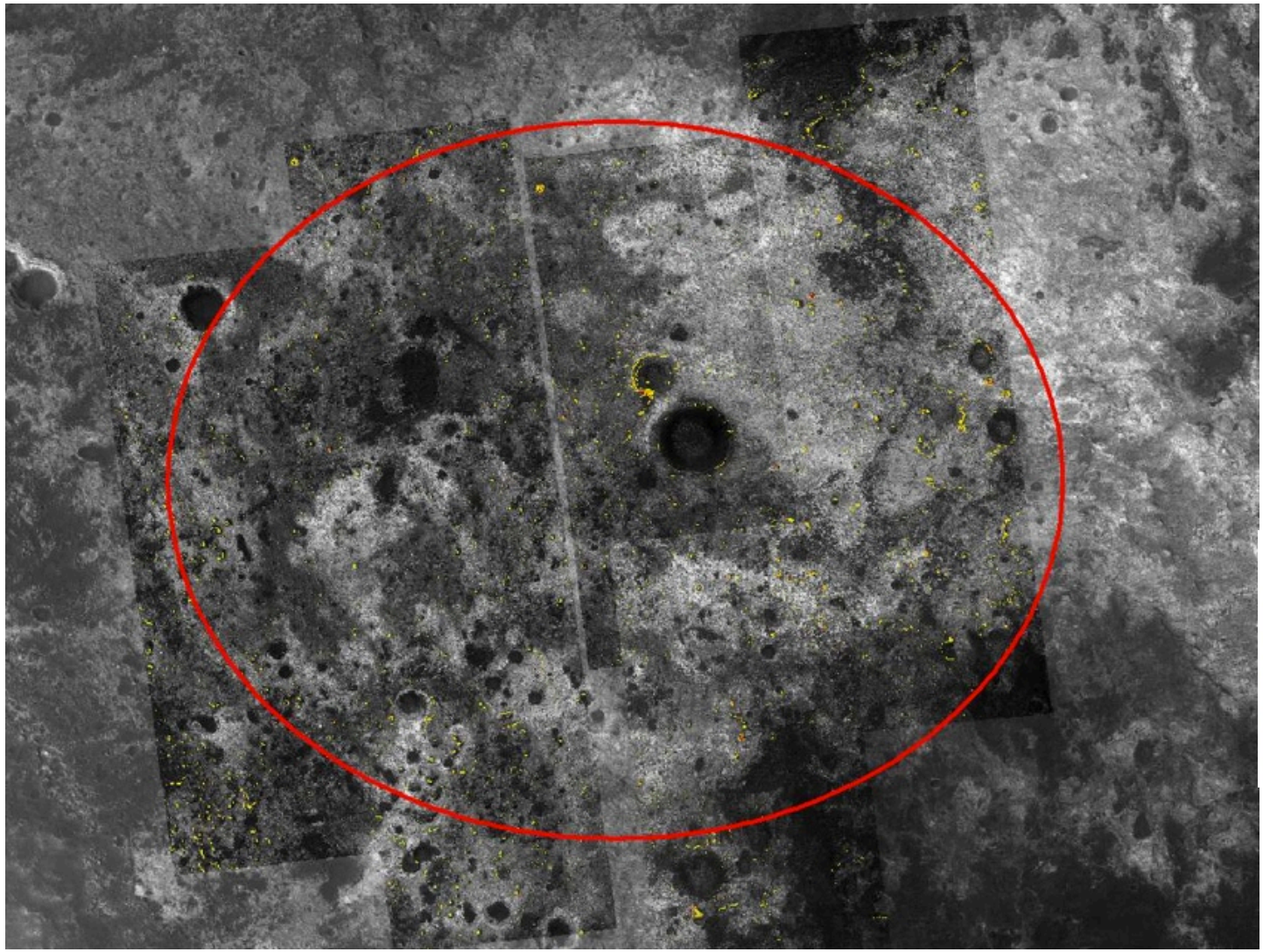


Holden

Slopes derived from HiRISE digital elevation model of R. Kirk (USGS) by F. Calef (JPL).

- <15 degrees
- 15-20 degrees
- 20-25 degrees
- >25 degrees

Slopes at 1-m Baseline



Mawrth

Slopes derived from HiRISE digital elevation model of R. Kirk (USGS) by F. Calef (JPL).

- <15 degrees
- 15-20 degrees
- 20-25 degrees
- >25 degrees

Summary

- **No new observational evidence since 2004 globally, or at our specific landing sites, that indicates water or water ice at latitudes equatorward of 30°.**
- This conclusion has been informally reviewed by external experts, including Mike Mellon (CU Boulder), who also addressed the NAC PP Subcommittee last week.
- Risk of undetected ground ice is very low due to:
  - Thorough scrutiny of these sites
  - Season and diurnal temperature ranges that preclude the accumulation of subsurface ice from atmospheric water vapor
  - Lack of appreciable area with thermal anomalies such as very low or high thermal inertias, shadowed areas, or poleward-facing high slopes